Investigation of a New Earthquake and Flood Alert System

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***Abstract*— Earthquake is a type of natural disaster which is difficult to predict while flooding is one of the common natural disasters in South East Asia. The effect of these disasters varies from death to property damage. People who engage in their daily activities sometimes panic and are clueless on the current situation around them when disasters happen. At this critical time, information on the disaster needs to be conveyed correctly and effectively in the area of the disaster as well as the neighbouring vicinity. To address this concern, authors devised an intelligent disaster alert system for earthquake and floods. The system detects the level of water and earthquake by using ultrasonic sensor and accelerometer and when a disaster occurs, sends alert and images of the disaster to a defined Telegram account which is accessible to anyone who installs the application in their mobile phone or Personal Computer. This is controlled by an embedded controller, Raspberry Pi which decides on the alert message to be sent based on the level of danger. Evaluations were done on the success rate of message delivery within a defined distance range. In the tests conducted in close vicinity (less than 1km distance between sender and receiver) and more than 5km distance, results showed that message reception from the sender was received an average of less than 2 seconds for text alert and less than 13 seconds for the image.**

***Index Terms*— Disaster Alert; Earthquake Detection; Safety Alert System; Telegram Messaging.**

I. Introduction

The effect of disasters in any country in the world range is sometimes tremendous since many lives and property damages hinder its sustainable growth. In Southeast Asia, serious flood disasters affect countries such as Thailand, Laos and Vietnam and even Malaysia. In Thailand, five districts were affected, seven bridges and more than 20 buildings were destroyed at Mae Hong Son while at Nan Province, the flood was affected 127 small districts and the flood water level up to 3 metres deep [1][2]. 4977 people were affected by the flooding happened in Laos. In Vietnam, seven people were died due to the Typhoon Dianmu, at least 44 homes were devastated by the storm, two people were missing during the flood, and more than 600 houses were destroyed. ther than flood disaster, the earthquake also happened worldwide during these days. In India, there was an earthquake happened on 12 October 2016 at 4.01am with a Richter scale of 5.3 hits Lakshadweep Sea area [3]. On 26 August 2016, there was an earthquake happened in Ranau, Sabah, East Malaysia at 9.39am, which measured 4.0 on the Richter scale and depth of 10km [4]. Climbers were rushing down quickly from 4095m peak of the mountain with the assistance of mountain guides. It was smaller in the magnitude when compared to the earthquake which happened on last year, 5 June at the same place but with the highest magnitude of 6.0 on the Richter scale which lasted for 30 seconds where it was the strongest earthquake that hit Malaysia since 1976. During that earthquake, 18 people died on the Mount of Kinabalu.

The common problem in disaster management is not the lack of technology or the presence of related information, but it is usually lack of accessibility of the information. The key spirit of investigating and identifying the solutions for disaster recovery are the ability to use, discover and manage the information efficiently. Therefore, it is crucial to determine and access the data efficiently in order to figure out the problem effectively. Besides that, there is a very high false alarm rate by the present warning system which is beyond weather forecasts. A real-time flood monitoring system requires sensing the flood conditions, which includes the presence of water, the level of water, the velocity of water and the rate of rain. Fixed water level sensors, satellites, and optical measurements are insufficient. Prediction of flood and earthquake disaster is also difficult as they can happen suddenly. Thus, precaution measurement cannot be taken out and inform to citizens. Hence, the information must be received in the least time to save human life. The earlier the disaster awareness or alert message received, the more life of people could be saved. Throughout the years, several flood and earthquake disaster messaging systems were developed using different communication mediums [5]-[11]. Another example of a LED messaging system that was developed and could be used for disaster alert is the Automated Remote Messaging System [12], although improvements should include sensors to detect the disaster.

It is important to get to know the disaster precautions in order to prevent the loss of human lives and minimizing the property damages. Hence, safety precautions and the alert system should be planned well before the disasters strike. An earlier developed system using a controller, but a different messaging application (Whatsapp) was developed but only developed for earthquakes disasters only [13]. Therefore, in this research, the main idea is to develop an alert system that will sense the earthquake and flood disasters, then display the warning or precaution message to people in the shortest time possible in order to reduce deaths and injuries that may happen. The objectives of this research are to design a disaster alert system that detects a low to high level of flood disaster and a medium range of earthquake disaster by using ultrasonic sensors and accelerometer respectively; to develop a disaster messaging system for sending alert information and image of water level condition by using USB camera through smartphone's application and to calculate the rate of efficiency for delivering and displaying the alert message with image.

II. MEASUREMENTS FOR EARTHQUAKE AND WATER LEVEL

A. Earthquake level measurement

An important part of any disaster alert system is the parameter measurement. To measure the strength of earthquakes, seismograph or seismometers are normally used. The networks of seismographs continuously record ground motion around the world in order to check and investigate the worldwide earthquake and other sources of seismic activity. To determine rate the magnitude of an earthquake, Richter scale or Mercalli scale can be used. Between the two, Richter scale is more commonly used. It is based on logarithmic scale. For instance, a moderate earthquake is rated at 5.3 magnitudes while a strong earthquake is rated at 6.3 magnitudes. Mercalli scale is based on the observations of people who feel or experience the earthquake. The relation between Richter scale, acceleration and Mercalli equivalent is shown in Table 1. In our approach, we will use 3-axis accelerometers to measure accelerations across axis of X and Y.

Table 1
Richter, Mercalli scales and approximate acceleration

Richter Scale	Approximate Acceleration (cm/s^2)	Approximate Mercalli Equivalent
<3.5	1	I
3.5	2.5	II
4.2		III
4.5	10	IV
4.8	25	V
5.4	50	VI
6.0	150	VII
6.5	250	VIII
6.9		IX
7.3	500	X
8.1	780	XI
>8.1	980	XII

This is because earthquakes can generate vibrations about a different axis. The accelerometer is placed inside a plastic container to ensure that the soil does not disrupt the measurement of the accelerations. To measure acceleration of the contained soil using accelerometer ADXL 335, required parameters are listed as in Table 2.

Table 2
Parameters required for acceleration measurements

Parameter	Value	Unit/symbol
Sensitivity	0.33	V/g / S
Voltage at 0 g	1.65	V
Analog to Digital Converter value	0 - 1023	Adc
ADC for x-axis	0 - 1023	adc_{Rx}
ADC for y-axis	0 - 1023	adc_{Ry}
Reference voltage	3.3	V / V_{ref}
Gravity force with respect to acceleration	9.81	m/s^2
Voltage difference between output voltage and V_{0g}	0-5	δV
Peak ground acceleration	a	m/s^2

To calculate gravitational force with respect to the acceleration, R_x:

$$R_x = \frac{1g * a(\frac{m}{s^2})}{9.81(\frac{m}{s^2})} \quad (1)$$

To calculate analog to digital converter (ADC) value, adc_{Rx}:

$$adc_{R_x} = \frac{[(R_x * S) + V_{0g}] * 1023}{Vref} \quad (2)$$

As an example, for an acceleration of 2.5 cm/s^2 or Richter Scale of 3.5 magnitudes (refer Table 1), R_x will be calculated as 0.00255, and its corresponding ADC value from Equation (2) is approximately 511.

B. Water Level Measurements

For measurements of water level in drainage or river banks, different types of sensors could be used, including infrared, ultrasonic, roadside, liquid sensors, and radars. Some researchers also combine multiple passive infrared sensors with ultrasonic rangefinders to monitor the presence of water level, pluviometry, vehicle speeds, counts, and density. For our research, we use ultrasonic sensors due to its fast response to detect the water level in an area. When there is a flood, the height of the water is above the safe level, and the controller could process the value of the height measured. The basic operation of an ultrasonic sensor is started by powering up the module. Next, a pulse of the high-level signal (5V) is supplied to the Trigger pin for at least 10us. Next, the module will automatically transmit eight cycle burst of ultrasound at 40 kHz and wait for the reflection. If there is an object (water) detected by the receiver, the Echo pin will be set to high (5V) and delay for a period which is proportional to the distance.

Table 3
Specifications of ultrasonic sensor HC-SR04

Features	Ultrasonic Sensor (HC-SR04)
Operating Voltage	DC +5V
Operating Current	15 mA
Operating Frequency	40 Hz
Range	2cm – 400cm
Measuring Angle	30 degree
Effectual Angle	<15 degree
Trigger Input Signal	10us TTL pulse
Echo Output Signal	Input TTL lever signal and the range in proportion
Dimension	45 mm x 20 mm x 15mm

Based on the working of basic principle that stated above, the timing diagram of distance measurement by ultrasonic sensor is shown in Fig.

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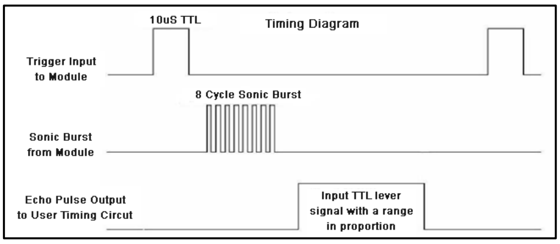


Figure 1: Timing diagram of distance measurement by the ultrasonic sensor

In order to obtain the distance between the ultrasonic sensor and the obstacles, the width of Echo pin is measured as in Equation (3). t, w, v, d, v_s denotes time (μs), echo width, the speed of pulse, distance and speed of sound.

$$t = w \tag{3}$$

Moreover, the general formula to calculate the distance is shown in Equation (4):

$$d = t \times v \tag{4}$$

Hence, the formula to measure the distance between the ultrasonic sensor and the object is shown in Equation (5):

$$d = \frac{t \times v_S}{2} \tag{5}$$

From Equation (5), the value '2' in the formula is due to the sound has to travel away from the sensor at first, then strikes to the surface and returns back. However, the common speed of sound is approximately 340 m/s and this value correspond to 29.412 us/cm, which is 29 us/cm after rounding off.

Therefore, to calculate the distance of the object (water) from the sensor;

$$d = \frac{t\,(us) \times 29\,(\frac{us}{cm})}{2} = \frac{t\,(\text{us})}{2} \times \frac{1\,(\text{cm})}{29\,(\text{us})} = \frac{t}{58}\ (\text{cm}) \tag{6}$$

III. System Design

Since the system requires testing to be done in physical hardware, we developed an experimental test system to address both earthquake and increase of water level simultaneously. This setup consists of ultrasonic and accelerometer sensors, Raspberry Pi controller and display device, a contained area for soil and sand separated with water, as shown in Figure 2.

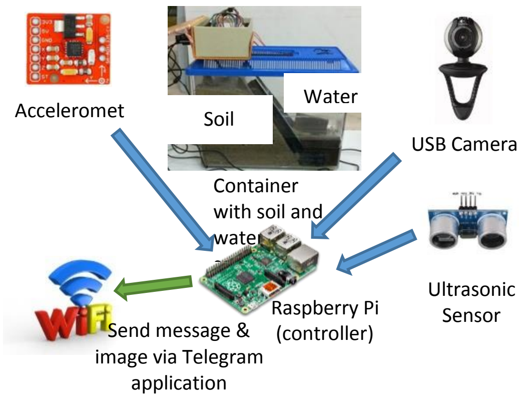


Figure 2: Experimental setup for the system

With ultrasonic and accelerometer sensor readings as inputs, the controller will decide whether the values surpass a certain threshold (representing a certain earthquake magnitude and water level) or not. This will determine the type of message delivered, indicating the level of danger. Along with this message, the USB camera will capture the image and send it as a picture via the same Telegram channel. An important condition during this process is that the wireless network connection must be available for successful message sending. Telegram is used as an application for sending from the Raspberry and users can receive the messages/images via the same application, provided that users install the application on their mobile phones or computers. The overall flow chart of the system is shown as in Figure 3. To validate the system developed, several experiments were performed. However, only the final results of indoor and outdoor message reception were presented in this paper to highlight the efficiency of the alert system. Prior to the experiments, the components were placed at fixed locations inside the container to ensure consistent measurement throughout the experiments. In the early stages, the ultrasonic sensor was tested without detecting the earthquake to ensure that the sensor detects the water level correctly. This was done by connecting a continuous flow of water to confirm the ability of the sensor to detect changing the water level. Then the accelerometer was tested without the ultrasonic sensor. The accelerometer was tested in X and Y axis respectively, the container is shaken manually by both hands and detecting values greater than a threshold which is indicated by LEDs. Both of the ultrasonic and accelerometer experiments are shown in Figure 3.

The next experiment was to test both sensors simultaneously, which includes the alert message and image. The image is captured by a camera connected to the Raspberry Pi with a resolution of 640 x 480 pixels. Once the system successfully demonstrated the success of disaster detection, the efficiency of the system is investigated. This is done by measuring the time needed for receiving the alert message with an image, experimented at indoor and outdoor locations. The flowchart for the system operation is shown in Figure 4. For outdoor locations, the distance between the alert system and user/receiver (smartphone) is divided into near distance (less than 1 km radius) and medium distance (more than 5 km radius). The process is repeated 10 times, and average and standard deviation values are calculated for the time of message and image reception.

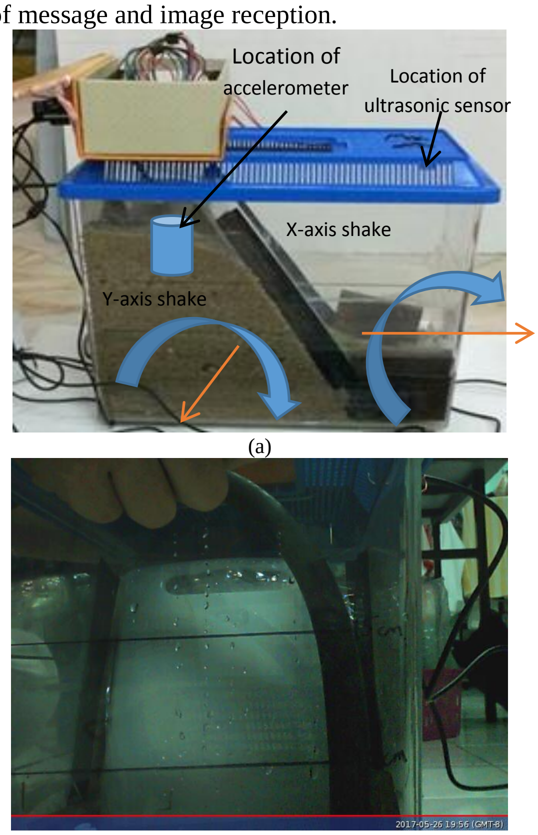


Figure 3: (a) Experimental setup measure magnitude of shake in X and Y-axis and (b) Experiment to test continuous water level measurement using ultrasonic sensor (sensor placed at the top of the case, facing the base)

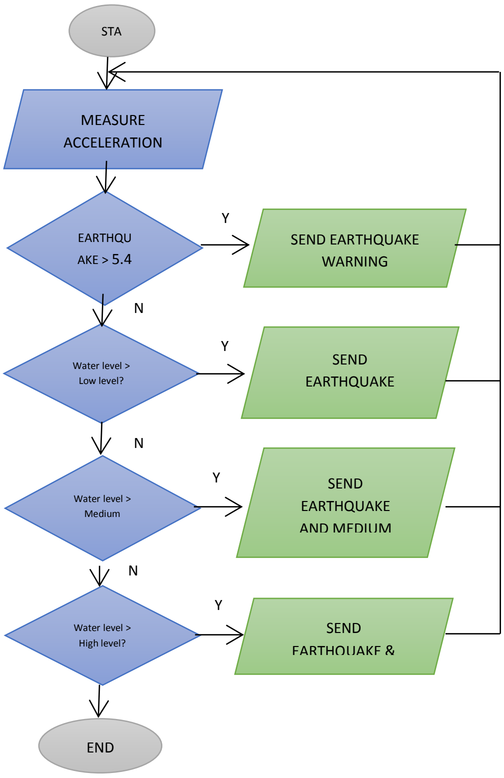
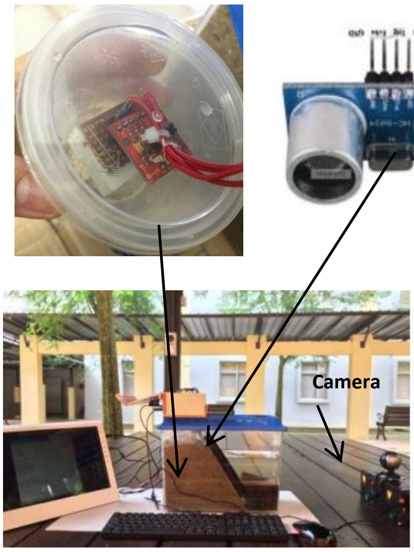
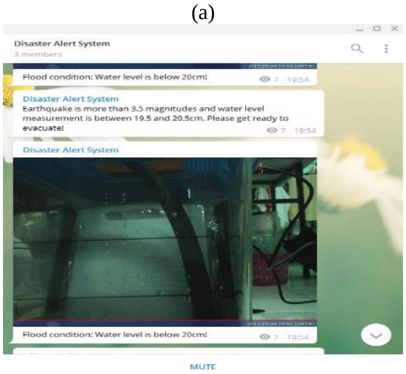


Figure 4: Flowchart of the system

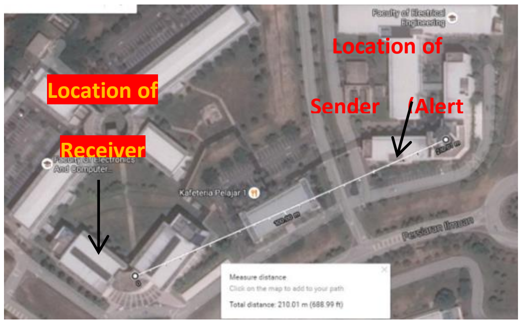


(a)

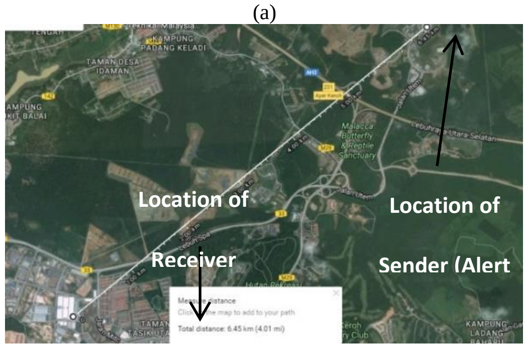


(b)

Figure 5: (a) The complete picture of the experimental setup and (b) proof of message received from user



(a)



(b)

Figure 6: Outdoor tests at (a) near distance (<1km) and (b) medium distance (>5km)

As seen in Figure 6, the outdoor tests performed involved two different locations, at a near distance of less than 1km and distance of more than 5 km. For the close distance, the neighbouring Faculty (Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer) was chosen as a location for the user to test the message/image reception while for the distance of more than 5 km, Fakulti Kejuruteraan Mekanikal, located at another campus (Ayer Keroh) was chosen. Tests were performed for X and Y accelerations at low, medium and high water levels for both text messages and images by shaking the container in each respective axis. Each water level values are indicated as LED outputs to show that the shake magnitude is greater than its threshold value. At each location of sender and receiver, coordination was done by communication over mobile phones and stopwatches.

IV. Results

The results of the experimental test on message and image receptions are shown in Tables 4 to 7. The equation for calculating the ADC value was shown in (2). Table 4 recorded the data for the acceleration ADC value of 511 which is equivalent to approximately 3.6 Richter magnitudes (refer to Equation (1) and (2)). As seen in Table 4, in a total number of ten trials, the time of reception of messages range from 0.9 to 3 seconds while the images were received within 9 to 15 seconds. In total average, messages were received less than 2 seconds while images were received in less than 12 seconds. At each X and Y axis of shake, low, medium and high level of water was tested.Table 5 shows the time taken for the recipient to receive messages and images at values of greater than 5.3 Richter scale (516 ADC value). The results vary from 0.7 to 2.1 seconds for messages while images were received between 9.1 to 15.1 seconds. In average, messages were received within less than 2 seconds and images in less than 13 seconds.

Table 4
Time taken for recipient to receive message and image at earthquakes between 3.6 and 5.3 Richter scale at outdoor test between FKE and FKEKK (<1km)

Number of Trials	Time Taken for Recipient to Receive Message and Image at 511 ADC Value between FKE and FKEKK (s)											
	Low Level				Medium Level				High Level			
	X - direction		Y - direction		X - direction		Y - direction		X - direction		Y - direction	
	Message	Image	Message	Image	Message	Image	Message	Image	Message	Image	Message	Image
1	1.7	13.0	2.5	10.6	1.2	11.0	2.0	11.5	2.4	12.6	2.1	10.4
2	1.2	11.2	1.0	9.9	1.8	12.3	1.3	10.7	1.1	9.9	1.5	10.1
3	3.0	10.8	1.3	9.7	1.0	10.0	1.5	10.1	1.5	11.0	1.2	9.5
4	1.3	11.2	0.9	11.3	1.1	11.0	1.1	11.0	1.9	11.4	1.3	10.7
5	2.6	8.3	1.1	11.9	1.1	10.3	1.4	10.7	1.3	11.0	1.0	9.5
6	1.7	9.4	1.0	9.7	1.7	10.4	1.3	11.8	1.2	11.5	0.7	11.0
7	1.8	14.9	1.2	9.1	1.2	10.3	1.4	10.3	0.9	13.6	0.9	9.9
8	1.4	10.6	1.0	10.3	1.0	10.5	1.1	10.0	1.0	9.8	1.1	11.2
9	1.3	11.3	1.3	9.2	1.4	10.8	1.7	10.2	1.8	11.6	1.7	11.0
10	1.0	15.0	1.0	10.5	1.1	12.5	1.0	9.7	1.4	11.3	2.0	11.8
Average	**1.70**	**11.57**	**1.23**	**10.22**	**1.26**	**10.91**	**1.38**	**10.60**	**1.45**	**11.37**	**1.35**	**10.51**
Standard Deviation	**0.64**	**2.16**	**0.47**	**0.89**	**0.28**	**0.85**	**0.30**	**0.67**	**0.46**	**1.13**	**0.47**	**0.76**

Table *5*
Time taken for recipient to receive message and image at earthquakes greater than 5.3 Richter Scale at outdoor test between FKE and FKEKK (<1km)

Number of Trials	Time Taken for Recipient to Receive Message and Image at 516 ADC Value between FKE and FKEKK (s)											
	Low Level				Medium Level				High Level			
	X - direction		Y - direction		X - direction		Y - direction		X - direction		Y - direction	
	Message	Image	Message	Image	Message	Image	Message	Image	Message	Image	Message	Image
1	1.0	9.1	1.1	12.1	2.1	18.5	1.0	11.9	2.0	13.7	1.8	10.4
2	1.7	9.6	1.0	11.0	0.8	11.0	1.5	11.3	1.3	10.7	1.1	11.9
3	1.5	10.7	0.9	10.5	0.9	9.5	1.1	11.2	1.1	12.3	1.0	11.2
4	0.7	10.0	1.0	11.5	1.2	9.4	1.2	15.1	1.5	13.6	1.2	10.7
5	0.9	9.9	1.2	10.4	1.3	10.1	0.9	11.3	1.8	11.4	1.5	11.6
6	1.0	10.8	1.5	10.0	1.0	9.6	1.0	11.1	1.0	10.6	1.3	11.0
7	1.2	10.5	1.3	10.6	1.2	10.4	1.2	13.2	0.9	10.3	0.9	12.2
8	1.1	11.4	0.8	10.5	1.1	11.0	1.1	11.6	1.7	12.2	1.1	10.5
9	1.3	10.4	1.1	11.5	0.7	10.5	1.1	13.7	1.2	10.4	1.7	13.6
10	1.0	11.1	1.0	11.8	0.9	11.2	0.8	11.6	1.4	10.3	1.2	11.6
Average	**1.14**	**10.35**	**1.09**	**10.99**	**1.12**	**11.12**	**1.09**	**12.20**	**1.39**	**11.55**	**1.28**	**11.47**
Standard Deviation	**0.30**	**0.70**	**0.20**	**0.70**	**0.39**	**2.67**	**0.19**	**1.35**	**0.36**	**1.33**	**0.30**	**0.96**

Table 6
Time taken for recipient to receive message and image at earthquakes between 3.6 and 5.3 Richter scale at outdoor test between FKE and FKM (>5km)

Number of Trials	Time Taken for Recipient to Receive Message and Image at 511 ADC Value between FKE and FKM (s)											
	Low Level				Medium Level				High Level			
	X - direction		Y - direction		X - direction		Y - direction		X - direction		Y - direction	
	Message	Image	Message	Image	Message	Image	Message	Image	Message	Image	Message	Image
1	1.2	11.3	1.4	13.0	1.8	12.6	1.2	12.0	2.8	14.5	1.5	11.3
2	1.8	11.8	1.0	11.9	1.0	12.7	1.0	10.8	1.5	12.4	2.1	10.8
3	1.1	11.4	1.7	10.4	1.0	12.9	0.7	12.2	2.1	11.3	1.0	10.9
4	1.4	10.5	0.8	12.0	0.9	13.2	1.0	11.2	1.4	10.5	1.4	11.2
5	1.5	12.0	1.3	10.3	1.1	11.5	1.1	12.0	1.3	11.0	1.1	11.5
6	1.6	11.5	1.1	11.4	0.8	11.1	1.6	12.7	1.0	10.0	1.8	11.0
7	1.2	14.0	1.5	11.8	0.9	12.9	1.3	11.3	1.4	12.2	1.2	11.3
8	1.1	10.9	1.0	11.2	1.2	11.6	1.4	12.7	1.9	10.7	1.2	12.1
9	0.8	13.4	1.0	12.3	1.1	11.2	1.0	11.2	1.1	10.8	1.6	10.8
10	1.2	11.4	1.1	11.3	1.5	11.8	1.2	12.0	1.5	11.3	1.5	10.4
Average	**1.29**	**11.82**	**1.19**	**11.56**	**1.13**	**12.15**	**1.15**	**11.81**	**1.60**	**11.47**	**1.44**	**11.13**
Standard Deviation	**0.29**	**1.09**	**0.28**	**0.83**	**0.31**	**0.79**	**0.25**	**0.66**	**0.54**	**1.29**	**0.34**	**0.47**

Table 7
Time taken for recipient to receive message and image at greater than 5.3 Richter Scale at outdoor test between FKE and FKM (>5km)

Number of Trials	Time Taken for Recipient to Receive Message and Image at 516 ADC Value between FKE and FKM (s)											
	Low Level				Medium Level				High Level			
	X - direction		Y - direction		X - direction		Y - direction		X - direction		Y - direction	
	Message	Image	Message	Image	Message	Image	Message	Image	Message	Image	Message	Image
1	1.1	12.8	2.2	11.2	0.9	14.2	1.3	12.1	2.3	12.4	1.7	12.4
2	1.9	10.8	1.7	12.8	1.2	14.0	1.0	10.9	1.5	14.5	1.1	12.5
3	1.3	12.0	1.1	11.4	0.9	12.1	1.2	11.2	1.9	14.0	1.3	11.5
4	0.9	12.6	1.3	10.0	0.8	11.0	1.0	11.7	1.3	11.2	1.0	10.3
5	1.2	11.2	1.4	12.8	1.0	12.2	0.9	12.0	1.1	13.7	1.1	10.8
6	1.1	11.8	1.8	12.3	1.3	11.6	1.5	12.9	1.1	11.6	0.9	10.0
7	2.1	10.2	0.9	10.9	1.1	10.8	1.1	11.9	0.9	12.4	0.9	10.8
8	1.5	12.3	1.0	11.0	1.1	10.7	1.8	11.7	1.7	11.0	1.5	11.0
9	1.0	11.9	1.3	12.1	1.0	11.5	1.3	11.9	1.4	11.8	1.1	10.9
10	1.3	12.7	1.5	11.5	1.4	12.1	1.0	11.6	1.2	10.6	1.3	14.1
Average	**1.34**	**11.83**	**1.42**	**11.60**	**1.07**	**12.02**	**1.21**	**11.79**	**1.44**	**12.32**	**1.19**	**11.43**
Standard Deviation	**0.39**	**0.86**	**0.40**	**0.90**	**0.19**	**1.22**	**0.28**	**0.54**	**0.42**	**1.34**	**0.26**	**1.24**

Although, the magnitude of shake is higher, message reception does not differ much as long as the sensor was able to detect the earthquake warning. For a distance of more than 5km, Table 6 shows the time taken for the recipient to receive messages and images at values of greater than 3.6 Richter scale but less than 5.3 Richter scale. The average time of reception for messages is less than 2 seconds and less than 13 seconds for images. For Richter scale of greater than 5.3 magnitudes, Table 7 shows the time taken for the recipient to receive messages and images. The average time of reception for messages is less than 2 seconds and less than 13 seconds for images. It was shown in all the investigated distances and magnitudes (from Table 4 to Table 7), the time to receive images were longer than the time to receive messages. This is expected due to the size of the images which are greater than the size (data) of text messages. The images were captured and sent at 640 x 480 pixels in all the experiments.

It is noted that text messages need to be received by the user in the shortest time. Tables 4 to 7 showed that an average of less than 2 seconds were produced and sufficient for the user to take necessary precautions or evacuate the area. The images are confirmation of the state of the disaster, giving actual pictures to show the level of water from the viewpoint of the camera. The images were received within less than 13 seconds which is acceptable. This showed an improvement than the earthquake disaster alert system shown in [13].

V. CONCLUSION

The intelligent disaster alert system is a new technology that was designed and developed to assist human beings in conveying disaster warning messages. It comprised of sensors and controller and uses Wireless Network to transmit warning messages to pre-defined Telegram accounts/bots. Two types of disasters were investigated which are earthquake and flood (water level). Testing of the system was done in two different location ranges, near within 1km and larger than 5km. The results have shown that text messages were received faster than images due to the size of data. It is crucial that the time of reception of messages were faster to ascertain that in the condition of emergency, evacuation or other necessary efforts could be coordinated faster. Images are just confirmation of the condition of disaster. The effect of increasing distance between disaster alert sensor and recipient are very insignificant because it depends on the broadband/wireless connections provided by the telco.

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